Design and laboratory tests of a long-life FM transmitter for tagging small mammals

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Problems involved in developing a long-life FM telemetry transmitter for tagging small mammals are described.

Tagging of animals for tracking and identification has been accomplished through a number of means. One of the best-known techniques is the placement of leg bands on birds to determine their migratory patterns. Field studies of small mammals have used techniques ranging from amputating the toes (toe clipping) of ground squirrels and similar species, to the use of dark dyes and tattoos (for instance, see Koford, 1965). Radio transmitters that can be attached externally or implanted in the organism are relatively new to the field; transistors, and other miniature electronic components have made extensive tracking possible (see Craighead, Craighead, & Davies, 1963; Mackay, 1968, 1969).

A few years ago researchers developed a unit to transmit signals from underwater, enabling tracking and biotelemetry of physiologic functions from fish (Lonsdale & Baxter, 1968). This paper describes a similar package capable of locating small mammals underground.

TRANSMITTER DESIGN AND OPERATING CHARACTERISTICS

One of the major problems in electronic tagging of small mammals for field research has been the relatively short life of the transmitter. Larger animals have little difficulty carrying the batteries necessary for operating a transmitter for extended periods of time. Work done at the

University of Wyoming on tagging fish has emphasized the need for a small unit with a long life expectancy (Lonsdale & Baxter, 1968).

Figure 1 shows the circuit diagram of the transmitter used in the present study. Circuit diagrams are described in the legend. It is fundamentally a Hartley Oscillator, but is triggered by an electronic switch. With the components shown, the transmitter operated at approximately 102 megaHz. The average current drain of the transmitter was 35 microamperes, and of the switching circuit, 5 microamperes. This produced an approximate total average current drain on the battery of 40 microamperes per cycle.

Lonsdale, Dunmire, and Brown (1964) suggested that these transmitters were highly temperature sensitive. At room temperature, an 800-Hz tone of 71 msec duration was transmitted approximately 58 times per minute.

Figure 2 shows the linear relationship between temperature and pulse length.

Figure 3 shows the linear relationship between temperature and the number of oscillations of each pulse. The transmitter ceased to operate at 15°C. The effects of extremely high temperatures were not tested.

The repetition rate, or number of pulses per minute, was not linear. It was fairly constant to about 30°C, and below that temperature fell off sharply. The circuit in Fig. 1 was designed to have a minimum life of 5 months. At room temperature, the minimum has been exceeded by 3 months and the operating characteristics were essentially unchanged. The unit ceased to

operate after 8½ months because of battery failure.

The range of the transmitter is approximately 200 m under optimum conditions. However, locating the transmitter at this range is difficult with hand-held portable FM radios. (The receiver used for this research was a Model 6518 Channel Master AM-FM unit.) At 50 to 75 m the pulsed tone was easily picked up, except when the transmitter was below the surface of the ground in a burrow. When underground, the unit could usually be detected at 5-10 m from the burrow.

The transmitter was assembled in three units: a battery pack, consisting of the two S76 batteries and capacitor C5; an oscillator unit consisting of Coil L, capacitors C₂, C₃, and C₄, resistors R₆ and R₇ and transistor Q₃; and a switch unit, consisting of the remaining elements. Any technician familiar with basic high-frequency assembly techniques should have no difficulty assembling the package. The main considerations require keeping the leads and connections as short as possible, and the coil relatively clear. These considerations can be achieved by using the transistors as central components in the switch and oscillator units, and adding the other components to the transistors. Connecting the three units is a simple matter since three leads connect the switch to the oscillator, and two leads connect the battery to the oscillator.

Prior to attaching the battery, the unit was bench tested on a bench power supply. Since it used so little current, it was necessary to place a microammeter or an oscilloscope in the circuit to determine if the unit was indeed drawing current. Two difficulties resulted in failure of the bench test; these were errors in connecting the various components because of the small size, and poor soldering technique. The

Fig. 1. Circuitry of transmitter. Components are listed below.

Q ₁ = 2N3905	R ₆ = 150K ohms
Q ₂ = 2N3903	R ₇ = 2.7K ohms
Q ₃ = 2N4254	C ₁ = 1mfd
R ₁ = 680K ohms	C ₂ = 51pf
R ₂ = 680K ohms	C ₃ = .012mfd
R ₃ = 330K ohms	C ₄ = 20pf
R ₄ = 150K ohms	C ₅ = 120pf
R ₅ = 1M ohms	B = two S76, 1½-V
	batteries; 165 mA h
	in series to give
	3-V supply

L = 1½ turns #16awg 1cm I.D.

All resistors 1/8 W, 10%; C₁, C₃—electrolytic tantalum; C₂, C₄, C₅—high quality silver-mica miniature units.

Fig. 2. Relationship between temperature in degrees Centigrade and tone length in msec. (Line fitted by least-squares method: $b_0 = -132.06$, $b_1 = 2.27$.)

small amount of current drawn was very sensitive to the resistance of solder joints.

Once the unit passed the preliminary bench test, the battery package was added. The battery pack was assembled by welding the connecting leads to the battery terminals. After the batteries were welded together, the unit was packed in fiberglass, and when the cement had dried, the package was filed down to a minimum size. The coating of fiberglass served to prevent pulling the brittle welded leads off the batteries. Capacitor C_5 was then attached to the battery unit, which was then attached to the oscillator unit.

The entire unit was dipped in fiberglass and rotated to obtain a complete thin covering of the components. Then a layer of Medical Silastic² was added to reduce irritation and rejection by the organism. [Our earlier biotelemetry units (i.e., Jackman, 1967) were packed in silicon jelly prior to adding coats of fiberglass and Medical Silastic in order to facilitate breakdown analysis.]

The unit was checked at each stage of the coating process by determining the carrier frequency. This was necessary because any material on or near the coil alters the Q of the coil, and hence changes the resonant frequency of the tank. For instance, touching the coil with a finger prior to coating results in sufficient loading effect to lower the carrier frequency below the broadcast FM band. After coating, the loading effect is much less, but the implanted unit broadcasts at from 2.7 megahertz lower than the same unit when tested on the bench. Immersion in salt water has nearly the same effect on the carrier frequency as implanting.

The unit when ready for implantation measured approximately 2½ cm sq x 1 cm thick and weighed 20 g.

LABORATORY TESTS

After construction, the unit was

implanted subcutaneously in the dorsal thoracic area of a White-tailed Prairie Dog (*Cynomys leucurus*). Previous implantations had been made ventrally in the abdominal area, and the transmitter was held in place with a suture. Healing was slow, probably because of the animal's activity and the pressure of the transmitter against the incision. In the dorsal implantation, the transmitter was not attached to the incision, but was left free. The incision was still slow to heal.

For about 10 days after implantation, the transmitter "drifted" down the right side of the animal, stabilizing on the right ventral side of the thorax. During this time the animal was confined to a relatively small cage, and his level of activity was limited. We do not know whether the animal's usual level of activity would have resulted in further migration of the transmitter, or whether the transmitter would have caused modifications in the animal's behavior patterns. After the transmitter had been implanted for 6 weeks, it was removed and examined for possible leaks or other damage. There were none.

DISCUSSION

The major advantage of the transmitter described in this paper is long life coupled with small size. Previous studies (Jackman, 1967) have shown that transmitters slightly larger than the pulsed toned transmitter have no effect on running speed of animals as small as the laboratory rat. Thus, the long life expectancy of this unit would enable long-term field investigation of animals as small as the Richardson Ground Squirrel.

Although some of the characteristics of the transmitted signal vary as a function of temperature, these variations are not large enough to provide the required sensitivity necessary for some types of research, and accurate measurement of temperature would require a different circuit design. However, for rough work the addition of a thermistor would enhance the existing temperature relationship so that the unit could be so used. Replacing R_6 with a thermistor of approximately the same value should enhance the relationship shown in Fig. 3. We have not explored this possibility since we were primarily concerned with tracking animals in the field, rather than telemetering physiologic information.

The unit failed to operate below 16°C because the transistors used did not have enough gain (high enough beta) to saturate the transistors. The simplest way to alleviate this problem would be to replace transistors Q_1 and Q_2 with a 2N2605 and a

Fig. 3. Relationship between temperature in degrees Centigrade and number of peaks per pulse. (Line fitted by least-squares method: $b_0 = 116.99$; $b_1 = 3.15$.)

2N484, respectively, or other high-gain transistors. Alternatively, the switch could be driven harder by reducing the value of R_1 or increasing the value of R_3 , but this would result in more current drain, and hence shorter unit life. We have not pursued this problem since the unit, as designed, works well with homeothermic animals.

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NOTES

1. Requests for reprints should be sent to Kenneth L. Jackman, Casper College, Casper, Wyoming 82601.
2. Medical Silastic. Trademark, Dow-Corning.